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Threatened Bliss Rapids snail's susceptibility to desiccation: Potential impact from hydroelectric facilities

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Abstract: Water levels in the regulated Snake River, southern Idaho, U.S.A. can fluctuate daily and seasonally due to hydroelectric demands. The federally listed threatened Bliss Rapids snail, *Taylorconcha serpenticola* Hershler *et al.*, 1994 (Family: Hydrobiidae), survives in and near these fluctuation zones. Remaining *T. serpenticola* populations occur only in sections of the Snake River that are impacted by these hydroelectric facilities and associated springs. Because effects of rapid draw-down in fluctuation zones on *T. serpenticola* are unknown, we conducted a laboratory experiment to evaluate potential impacts of desiccation. Our experiment compared desiccation resistance at several air temperatures, on dry and wetted substrates, and for 'small' vs. 'large' snails. Probit regression-maximum likelihood models estimated lethal time (LT_{50}) values. Survival was significantly greater on wetted substrate than on dry substrate and was lowest at temperatures <0°C and at 37°C on dry substrate. Survival was greatest at 17°C on wetted substrate. There was no significant difference in survival at temperatures above 0°C on dry substrate other than at 37°C. LT_{50} survival ranged from 0.5 hours at −7°C to 157.0 hours at 17°C on wetted substrate. There were no significant differences in survival relative to snail size in any treatment. Our results suggest that desiccation could impact *T. serpenticola* populations if snails become stranded on dry substrates during rapid water-level fluctuations of the Snake River, particularly during subzero winter or extreme high summer temperatures. The most important factor determining survival would be the ability to find refuge on the undersides of cobbles, where snails typically occur, or in habitats that remained moist for the duration of the draw-down of the river.

Key words: regulated rivers, probit regression, population viability, threatened species, Snake River

The federally listed, threatened Bliss Rapids snail *Taylorconcha serpenticola* Hershler *et al.*, 1994 (Family: Hydrobiidae) (Fig. 1) occurs only in fragmented populations within approx. 80 river kilometers of un-impounded sections of the regulated Snake River and in associated cool to cold-water springs of the Snake River aquifer, south-central Idaho, U.S.A. (Upper Snake River Basin) (Hershler *et al.* 1994, Richards 2004, Richards *et al.* 2006) (Fig. 2). Water levels in the un-impounded sections of the river fluctuate daily and seasonally depending on flows, location, geomorphology, and weather conditions. Daily fluctuations, mostly a result of hydroelectric generation from three dams in this area (Fig. 2), occur for only several hours at a time (Stephenson *et al.* 2004). Populations of *T. serpenticola* occur within fluctuation zones and may be affected by daily fluctuations, whereas spring populations are not subjected to these same fluctuations. Direct effects of rapid dewatering on individual *T. serpenticola* survival are unknown.

Taxonomic history and status of *Taylorconcha serpenticola*

Taylorconcha serpenticola was first collected in the Snake River of south-central Idaho and recognized as a new taxon by Taylor in 1959 (Taylor 1982). The taxon, although apparently collected and noted as early as 1884, went undescribed until Hershler *et al.* (1994) placed the snail in the new genus *Taylorconcha* and a new species, *Taylorconcha serpenticola*. Hershler *et al.* (1994) described the known distribution of this species as the main stem Snake River and associated springs of south-central Idaho.

The origins of *Taylorconcha serpenticola* are distinct in the molluscan fauna. *Taylorconcha* can be traced back to the late Pliocene (Blancan) Glenns Ferry formation in Gooding County, Idaho; the early Pleistocene Bruneau formation in Owyhee County, Idaho; and the late Pleistocene and probable Holocene deposits in Gooding County (Smith *et al.* 1982, Hershler *et al.* 1994). Of equal significance, *Taylorconcha* can be identified as a survivor of the Pliocene Lake Idaho, geologically dated about 3.5 Ma (Hershler *et al.* 2006).

Taylorconcha is one of the few remaining extant taxa from ancient Lake Idaho, which once supported a molluscan fauna of more than 80 endemic taxa (Hershler *et al.* 1994). Lake Idaho was thought to have extended from the border between western Idaho and eastern Oregon upstream of Hells Canyon eastward to a point near American Falls, Idaho (Taylor 1985, Hershler *et al.* 1994). Remnant populations of *T. serpenticola* remain in Idaho, inhabiting approx. an 80-km stretch of the Snake River upstream and downstream of Hagerman, Idaho in the Thousands Springs reach of the Snake River. *Taylorconcha serpenticola* was known historically from the main stem middle Snake River and associated

Figure 1. Male *Taylorconcha serpenticola.* Photo courtesy of Dan Gustafson, Montana State University, and David Richards, Eco-Analysts Inc., Center for Aquatic Studies, Bozeman, Montana.

springs between Indian Cove Bridge (Rkm 845.6) and Twin Falls (Rkm 982.5) (Hershler *et al.* 1994). Taylor (1982) believed that prior to dam construction there was probably a single population throughout this range.

The status of extant *Taylorconcha serpenticola* populations is a topic of concern. Federal action began on the species primarily in response to petitions submitted in 1980, under section 4(b)(3) of the Endangered Species Act (ESA) 1973. The snail was a candidate for category 1 listing from 1984 through December 18, 1990. This 1990 proposed rule listed *T. serpenticola* as an endangered species along with four other aquatic snails: the Snake River physa *Physa natricina* (Taylor, 1988), the Idaho springsnail *Pyrgulopsis idahoensis* (now Jackson Lake springsnail *Pyrgulopsis robusta* (Walker, 1908) (see Hershler and Liu 2004), the Utah valvata *Valvata utahensis* (Call, 1884), and the Banbury Springs *Lanx* (Frest, 1988) (limpet). On December 14, 1992, the U.S. Fish and Wildlife Service classified *T. serpenticola* as threatened while still taxonomically an "undescribed Hydrobiid" (U.S. Fish and Wildlife Service 1992).

Potential susceptibility of *Taylorconcha serpenticola* to desiccation

Taylorconcha serpenticola is the smallest (2.0-4.0 mm) of the Snake River hydrobiids in south-central, Idaho, and of those that we have observed, it is also the slowest moving (Richards 2004). Field trials indicated that *T. serpenticola* could travel approx. 1 to 10 cm/hour in water, which was more than ten times slower than the common pebble snail, *Fluminicola* (Carpenter 1864), and up to 100 times slower than the invasive New Zealand mudsnail *Potamopyrgus antipodarum* (Gray, 1843) (Richards and Arrington, unpubl. data). Thus, *T. serpenticola* is perhaps the least able of the hydrobiid species to actively avoid desiccation in fluctuation zones in the Snake River.

Life history and temporal environmental conditions may also affect *Taylorconcha serpenticola*, as has been shown for *Potamopyrgus antipodarum* survival probability to desiccation (Richards *et al.* 2004). Their results showed that: (1) smaller size classes had lower survival than larger size classes; (2) higher temperatures were related to decreased survivability; (3) freezing rapidly decreased survival; and (4) survival was greater at higher than lower humidity.

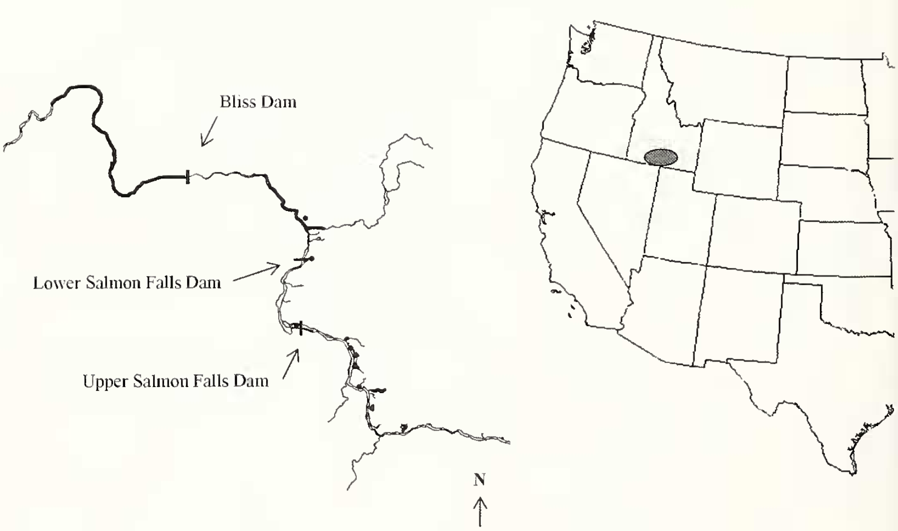

Figure 2. Current known distribution (approx. 80 river kilometers) of *Taylorconcha serpenticola* in the upper Snake River basin, south-central Idaho, U.S.A. Dark lines and dots indicate current known locations of the species.

Although *Taylorconcha serpenticola* is potentially susceptible to high rates of desiccation-induced mortality, this species, like all hydrobiid snails, has an operculum, which may help it survive. Winterbourn (1970) reported that *Potamopyrgus antipodarum* from New Zealand was able to survive desiccation for up to 50 days on a wetted substratum at 20-25°C. Richards *et al.* (2004) showed that *P. antipodarum*, in the western U.S.A., a parthenogenic clone, can survive desiccation on wetted substratum at 9°C for at least 48 hours.

The purpose of this study was to evaluate the survival probability of different sizes of *Taylorconcha serpenticola* under different time periods of desiccation at various temperatures and substrates (dry and wetted). Based on results of effects of desiccation on *Potamopyrgus antipodarum* (Richards *et al.* 2004), we hypothesized that *T. serpenticola* survival probability to desiccation was: (1) positively correlated with snail size, (2) negatively affected by increased temperature, (3) greater on wetted substrate than on dry substrate, and (4) negatively affected by freezing.

MATERIALS AND METHODS

Raising and rearing procedures

Taylorconcha serpenticola used in our experiments were from brood stock (250 individuals) collected in 1999 at the outlet of Banbury Springs, near Hagerman, Idaho. The *T. serpenticola* population at the outlet of Banbury Springs had the highest densities reported for any *T. serpenticola* population (>3000/m^2 in summer)(Richards 2004) and was considered the least likely population to be affected by 'harvest' for our experiments. Brood stock was supplemented with 100-200 individuals once to twice per year from the same source, until 2005. The collected snails and offspring were reared at EcoAnalysts Inc. Research Laboratory, Bozeman, Montana under the authority of a U.S. Fish and Wildlife Service Section 10 permit. *Taylorconcha serpenticola* populations in the lab were maintained in twelve to sixteen, 37.85-L aquaria at 16-17°C. Varying light: dark regimes were used to simulate or accelerate natural light conditions and seasons in an effort to produce more snails. All aquaria had substantial aeration, moderate flow, and contained various substrates, including periphyton-covered cobbles (food resource) that were collected from the outlet of Banbury Springs and the Snake River. Aquaria also contained native aquatic macrophytes including *Myriophyllum* sp., *Ceratophylum* sp., and *Elodea* sp. *Taylorconcha serpenticola* reproduced slowly in the laboratory (<5-7 eggs/year) (Richards and Arrington, unpubl. data); therefore, the number of individuals available for potential experimental sacrifice restricted experimental designs.

Experimental design

Twenty 'small' (1.50-2.00 mm shell height) and twenty 'large' (2.01-2.50 mm) *Taylorconcha serpenticola* were exposed to six air temperatures (−7, 0, 7, 17, 27, and 37°C) on two substrate conditions (dry and wetted) and ten time periods (2, 4, 8, 16, 24, 48, 72, 96, 120, and 144 hours for 0, 7, 17, and 27°C; 0.5, 1, 2, 4, 8, 16, 24, 48, 72, and 96 hours at −7 and 37°C). At −7°C only one substrate was used (dry) and at 7°C only one size class was used (1.5-2.50 mm). A total of 4360 snails were assayed in this experiment. The experiment was conducted in September 2004. The six temperatures were selected based on conditions likely to be encountered by *T. serpenticola* in the Snake River throughout the year. Based on past experiments (Richards 2004), a water temperature of 17°C appears to be the best temperature to promote *T. serpenticola* growth. The two substrate treatments were chosen to simulate conditions that *T. serpenticola* would encounter either on the tops of cobbles (dry) or the bottoms of cobbles (wetted) during dewatering.

Twenty 'small' and twenty 'large' *Taylorconcha serpenticola* were uniformly distributed on either a dry paper towel or wetted paper towel within a large, covered Petri dish. To reduce the effect of run order, the sequence of temperature treatments was randomized. Dishes were then placed in an environmental chamber and held at the appropriate temperature. Snails were removed from the chamber after the appropriate treatment interval and were transferred into new dishes filled with aquaria water at 15 to 17°C. After one hour in the water-filled dish, snails were observed to see if they opened their opercula and started crawling or if they were attached to the dish. If snails were crawling or attached to the dish, they were classified as 'alive'. If snails were not moving or not attached to the dish, they were observed under a dissection scope at 40× magnification; if no movement was apparent, snails were classified as 'dead'. Snails classified as 'dead' were then re-observed after 24 hours in water-filled Petri dishes. If snails were crawling or attached to dishes they were classified as 'alive'; if there was no observed movement, they were classified as 'dead'. Mortalities were kept as voucher specimens at EcoAnalysts Inc. Research Laboratory, Bozeman, Montana.

As a control, 20 'small' and 20 'large' *Taylorconcha serpenticola* were placed into two separate Petri dishes that were filled with aerated aquaria water for 120 hours. Controls were maintained at ambient lab temperature (16-17°C) and replenished with aquaria water as needed.

Probit regression was used to develop distribution models of survival for both 'small' and 'large' snails at the six temperatures. This method is widely used to evaluate dose/response of pesticides on insects and in medical studies (Finney 1971, Preisler 1988, Preisler and Robertson 1989, Baker *et al.* 1995, Peng *et al.* 2002). Compared with an

ANOVA, ANOVAs only determine if there is a significant difference between treatments, but probit analysis determines significant differences between treatments at any desired percent survival level. Probit analysis also models the relationship between percent survival and duration of exposure at any given temperature.

The most appropriate probit regression distribution model (Weibull, normal, lognormal, logistic, etc.) with 95% confidence intervals (CIs) was selected using maximum likelihood methods. Pearson chi-square goodness-of-fit tests were used for evaluating and selecting models. Goodness-of-fit tests were also used for comparing slopes of models. In addition, probabilities of survival, including LT_{50} values, were calculated; these are commonly used metrics for invertebrate bioassays (Dunkel and Richards 1998). A LT_{50} is the lethal time (or temperature) at which 50% of individuals being tested have died.

Treatment effects were considered significant if there was no overlap in 95% CIs of the probit models. All analyses were conducted using MINITAB 14.1 (Minitab Inc. 2003) and S-PLUS 6.1 (Insightful Corp. 2002).

RESULTS

Probit survival distributions were highly variable between treatments and significantly greater on wetted substrate than on dry substrate for both 'small' and 'large' snails

Table 1. Probit regression models and LT_{50} values of *Taylorconcha serpenticola* survival probability to desiccation, using best-fit maximum likelihood estimates. NA, not applicable.

Temp.	Best-fit probit regression model distribution	Pearson χ^2 goodness-of-fit test (*df, P*-value)	χ^2 test for equal slopes (*df, P*-value)	Log-likelihood	LT_{50} hr (95% CI)	
					Small	Large
−7°C	Weibull	1.68 (17, 1.00)	0.11 (1, 0.74)	−47.49	0.47 (0.34, 0.60) Dry 6.82 (2.53, 8.66)	0.47 (0.33, 0.60) Dry 8.75 (6.88, 11.08)
0°C	Lognormal	30.21 (35, 0.70)	8.39 (3, 0.04)	−221.78	Wetted 28.90 (23.15, 35.85)	Wetted 26.98 (21.64, 33.41)
7°C[a] (Dry)	Normal	0.07 (7, 1.00)	NA	−31.55	4.20[a] (2.45, 5.42)	
7°C[a] (Wetted)	Lognormal	7.83 (9, 0.55)	NA	−102.15	73.33[a] (57.04, 108.37)	
17°C (Dry)	Weibull	5.68 (17, 0.99)	2.23 (1, 0.14)	−69.49	2.33 (1.87, 2.97)	3.14 (2.61, 3.88)
17°C (Wetted)	Logistic	25.25 (17, 0.09)	0.09 (1, 0.76)	−100.07	131.96 (115.93, 154.09)	156.56 (140.58, 181.08)
27°C (Dry)	Weibull	5.38 (17, 0.99)	1.28 (3, 0.26)	−80.98	2.26 (1.82, 2.84)	3.22 (2.57, 4.07)
27°C (Wetted)	Logistic	13.50 (17, 0.70)	0.01 (3, 0.94)	−178.32	89.87 (75.87, 106.36)	88.59 (74.70, 105.91)
37°C	Lognormal	28.90 (35, 0.76)	5.21 (3, 0.16)	−289.41	Dry 0.98 (0.64, 1.47) Wetted 3.08 (2.16, 4.34)	Dry 1.52 (1.02, 2.21) Wetted 3.38 (2.38, 4.73)

[a] At 7°C only one size class was used (1.5-2.50 mm) due to limited number of snails available.

within each temperature treatment (Table 1). Survival was slightly less for 'small' snails than 'large' snails within each temperature treatment at most temperatures on both dry and wetted substrates but was not statistically significant (Table 1). Survival consistently decreased with increased desiccation times. Survival was significantly lower at −7°C than for any other temperature and almost identical for 'large' and 'small' snails (Table 1). Snails on wetted substrate survived >15 times longer than snails on dry substrate at 7°C (Table 1), and snails on wetted substrate survived >50 times longer than snails on dry substrate at 17°C (Table 1). There were no mortalities for 'small' snails ($N = 20$) and a single mortality (5%) for 'large' snails ($N = 20$) in the controls. Therefore, survivability was considered to be a result of treatment effects (*i.e.*, desiccation).

DISCUSSION

Our experiments showed that temperature and substrate moisture level could affect survival of *Taylorconcha serpenticola* to desiccation under controlled conditions. Our experiments simulated conditions that would occur on the tops (dry) and bottoms (wetted) of cobbles during flow fluctuations in the Mid-Snake River. Given that *T. serpenticola* moves relatively slowly (Richards 2004), its ability to avoid rapidly retreating water levels is limited. Therefore, the most important factor for individual survival is snail location at the time of receding water levels. Survival may be dictated by whether snails: (1) become stranded on the tops or sides of cobbles, where desiccation to temperature extremes is more likely, or (2) find refuge on the undersides of cobbles or in habitat that remains moist for the duration of the drawdown of the river.

Richards (2004) documented the snail's preference for sides or undersides of cobbles at the outlet of Banbury Springs and that it was only occasionally found on tops of cobbles. Bowler (2001) reported nocturnal movement of *Taylorconcha serpenticola* from the bottom to tops of cobbles. This preference for undersides of cobbles or 'photophobic tendency' may benefit *T. serpenticola* during rapid dewatering of shoreline habitat. Richards *et al.* (2005) and Stephenson *et al.* (2004) reported that densities of *Taylorconcha* are often greatest at shallow depths near the shoreline. Because these habitats are the most intensely affected by fluctuating river levels, a higher proportion of the river populations may be subjected to desiccation. Due to different shoreline topographies, it is impossible to determine fluctuation levels at any one location in the river and therefore, how much *T. serpenticola* habitat or what percentage of the population is affected at any point in time.

No research has been conducted on which stages of its life cycle are the most critical to population viability. For example, egg survival may be less important to population viability than survival of larger, more fecund adults or small to medium-sized snails that may have greater lifetime reproductive potential (Beissinger and McCullough 2002). It is also unknown if there is a seasonal effect of exposure on *Taylorconcha serpenticola* survival due to density-dependent interference or exploitative intraspecific competition. There is ample evidence for density-dependent regulation occurring in river invertebrate populations, including snails (McAuliffe 1984, Hart 1985, 1987, Lamberti *et al.* 1987, Osenberg 1989, Peckarsky and Cowan 1991, Kohler 1992, Anholt 1995) and possibly *T. serpenticola* (Richards and Arrington, unpubl. data). Exposure may reduce intraspecific competition of *T. serpenticola* by reducing densities, but may increase interspecific competition. For example, *Potamopyrgus antipodarum* and *T. serpenticola* are often found together in the Snake River fluctuation zones and have been shown to compete for limited food resources under *in situ* experiments (Richards 2004). Because *P. antipodarum* is better able to actively avoid exposure than *T. serpenticola*, flow-fluctuations may favor *P. antipodarum* over *T. serpenticola*, thus giving the former species an additional competitive advantage. Other biotic factors that were not evaluated, such as increased predation or parasite load, may also affect *T. serpenticola* survival during exposure.

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